Radar Observing System for Europe at L-band (ROSE-L)

M. Davidson, ESA/ESTEC

ROSE-L Mission Advisory Group

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- Gaia Vaglio Laurin, University of Tuscia, Italy
- Marco Lavalle – NASA/JPL (NASA Observer)
Copernicus 1.0 – The Present

**S-1**
- High Resolution Radar
- **A** 3 Apr. 2014
- **B** 25 Apr. 2016
- **C** 2022
- **D** > 2024

**S-2**
- High Resolution Optical
- **A** 23 Jun. 2015
- **B** 6 Mar. 2017
- **C** 2023
- **D** > 2025

**S-3**
- Medium Resolution Optical & Altimetry
- **A** 16 Feb. 2016
- **B** 25 Apr. 2018
- **C** 2023
- **D** > 2025

**S-4**
- Atmospheric Chemistry (GEO)
- **A** 2021
- **B** 2027

**S-5P**
- Atmospheric Chemistry (LEO)
- 13 Oct. 2017
- **A** 2021
- **B** 2027
- **C** > 2027

**S-5**
- Atmospheric Chemistry (LEO)
- **A** 2020
- **B** 2025
- **C** > 2027

**S-6**
- Altimetry
- **A** 2022
- **B** 2023
- **C** > 2027

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Copernicus 1.0 – The Present

*Copernicus 1.0 – The Present*
Copernicus Space Component - Long Term Scenario

- 4 Next Generation Missions (S1 NG, S2 NG, S3 OPT NG, S3 TOPO NG)
- 6 High Priority Candidate Missions (HPCMs)
- Invitation to Tender for Phase BCDE1 for all 6 HPCMs issued as of Nov 1\textsuperscript{st} 2019
ROSE-L Mission Background & Justification

- Mission objectives related to Copernicus service needs (*NEXTSPACE-SC3* study with EC Copernicus Service evolution documents, workshops), EC policies and Emerging Domains
- Address important *measurement gaps* from space
  - leverage unique information provided the longer L-band wavelength (23cm vs 5cm for C-band)
  - new information addresses gaps multiple applications and Copernicus services
- Support *enhanced continuity* of current Copernicus observations e.g. improved accuracy, product quality, temporal and spatial resolution
  - Enable joint use of L-band SAR with Sentinel-1 at C-band to enhance information and improve revisit
Derivation of mission requirements

**European Needs**
- EC Policies and associated
- Services and Service
- Emerging domains

**Requirement Sources**
- EC User Requirement Study
- EC User Workshops
- Task Force (s)
- Consultation Member States

**Types of requirements**
- Observation Gaps
- Enhanced continuity
- Continuity

**ROSE-L Objectives**
- Copernicus Missions
- ROSE-L Objectives
- Internationally context

**Mission Products**
- Product 1
- Product 2
- Product 3
- Product 4
- Product ...

**Mission Specification**
- Mission Requirements
- System requirements
ROSE-L Mission Objectives Overview

Fill measurement gaps from existing Sentinels, leveraging unique all-weather information provided at L-band:

- Ground motion information under vegetation
- Enhanced high-resolution sea ice information
- High resolution soil moisture information over land
- Enhanced Land use, Land use change, forestry and agriculture products
- Inundation/flooding below vegetation
- Improved Maritime Monitoring

Enhanced continuity of current Copernicus SAR observations e.g. improved accuracy, product quality, resolution

- Enhanced revisit
- Enhanced information content through combination of L- and C-band (Sentinel-1)
Data use, Land use change, forestry and agriculture

Justification and Uniqueness:
- High-resolution monitoring of changes in global forest carbon stocks and their spatial distribution
- High-resolution soil moisture information to support improved management of water use
- Enhanced weather-independent land cover and crop information
- Address cross-cutting information needs in Copernicus services (CLMS) and EU Policies (REDD+, EU Forest Strategy, EU 2020 Biodiversity strategy...)

Key Information products:
- Forest Biomass
- Forest Area (Forest/Non-forest) and Area change
- Land cover and Land Cover Change
- Irrigation Events
- Soil moisture
- Crop Type and Status

Above-ground forest biomass (Stelmaszczuk-Górska et al., 2018)
L-band SAR image of agricultural area
Example iceberg using C- and L-band

- ESA-JAXA agreement to coordinate PalSAR and Sentinel-1 acquisitions over limited number of test sites
Key Mission Requirements

- Stringent revisit requirements to meet needs of specific products e.g. soil moisture
  - 6 days (Equator)
  - 3 days (Europe)
  - 1 day (Arctic)
- Sentinel-1 orbit & coverage to maximise synergy
- Minimise number of instrument modes
  - Design a “preferred mode” meeting known user requirements
- Enable consistent long-term time-series over Europe and World
- Avoid conflicting requests from users which interrupt time series

MRD v2.0 currently public document: https://tinyurl.com/v825efb
Key Mission Requirements

- Polarisation diversity to maximise information content and robustness of information extraction (dual-pol and full-polarimetry)
- High-resolution e.g. 50m² per resolution cell for enhanced continuity
- Radiometric stability 0.5dB to ensure consistent and repeatable geophysical retrievals
- Interferometry to monitor surface deformation and motion
- Stringent data latency requirements: 10min over Europe, 200min
- AIS-onboard to support Maritime Monitoring
- Wave-mode to operate over oceans and open seas
Resolution is an important mission design parameter.

Two aspects need to be considered in defining resolution requirements for SAR missions:

1. the desired resolution for the information product
2. the acceptable uncertainty in radar image product

Careful analyses and interpretation of user requirements (in general as high as possible)

- European forests (0.25 – 0.5 Ha)
- Agriculture, land cover and soil moisture at field scale (0.1 – 0.5 Ha)

Choose resolution of 50m2/res cell for baseline dual-pol mode

<table>
<thead>
<tr>
<th>ENL</th>
<th>90% confidence</th>
</tr>
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<tbody>
<tr>
<td>50</td>
<td>ENL = 50 or 1dB uncertainty at 0.25Ha</td>
</tr>
<tr>
<td>100</td>
<td>ENL = 100 or 0.6 dB uncertainty at 0.5 Ha</td>
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</table>
ROSE-L radiometric stability - context

- Challenge to trace radiometric resolution to user requirements and in specification
  - Continuity argument: as good or better than existing satellites
  - Dynamic range of L-band SAR signal as function of geophysical parameter of interest e.g. contrast in land cover classes
  - Radiometry allocation to ionosphere and satellite
- 0.5dB radiometric stability mission goal. Error does not dominate at 50L/2db class contrast

Davidson et al. (2009)
ROSE-L Imaging Modes

- dual-polarization: nominal mode for systematic imaging of global land and ice
- quad-polarization: for specific applications
- wave mode: providing systematically vignettes over open ocean

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dual-pol</th>
<th>Quad-pol</th>
<th>Wave Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground resolution cell</td>
<td>&lt; 50 m²</td>
<td>&lt; 100 m²</td>
<td>&lt; 50 m²</td>
</tr>
<tr>
<td>Swath/coverage</td>
<td>&gt; 260 km</td>
<td>&gt; 260 km</td>
<td>Vignettes: 20 km x 20 km</td>
</tr>
<tr>
<td>Incidence angle</td>
<td>25° – 46°</td>
<td>fixed within 25°–46°</td>
<td>varying within 25°–46°</td>
</tr>
</tbody>
</table>
Other key system and mission parameters

- Swath width: 260 km
- Azimuth resolution: 50m² e.g. 5 x 10m
- NESZ < -28 dB
- Total ambiguities < -25 dB
- Dual-pol (baseline) + quad-pol mode at lower resolution (100m²)
- L-band
- VEGA-C launcher
- High Duty Cycle

= Challenging Requirements but Phase AB1 results indicate feasible
Conclusions

• ROSE-L is a L-band SAR mission currently and is one of the six Copernicus High Priority Expansion missions
• ROSE-L leverages unique information only available through the longer L-band wavelength to address measurement gaps and meet need for enhanced information products of Copernicus Services and in support of European policies
• Invitation for Phase-B2CDE1 issued on Nov 1\textsuperscript{st} 2019 with deadline on March 2\textsuperscript{nd} 2020. Expect to kick-off project with industry by June 1\textsuperscript{st} 2020
• ROSE-L launch foreseen in mid-2027
• ROSE-L as the “first” L-band SAR mission in the 2028+ timeframe should play an important role as an “anchor point” for international collaboration
  • First step: ESA-JAXA agreement for dedicated acquisitions with ALOS PalSAR-2 mission and Sentinel-1